Using AUVs and Sources of Opportunity to Evaluate Acoustic Propagation

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LONG TERM GOALS

To develop a passive autonomous and mobile system to investigate all types of noise in the ocean, both manmade and naturally occurring. The information will be used to improve the understanding of the noise field and the environmental factors which affect the noise in coastal regions.

OBJECTIVES

The objective of this project is to develop an ambient noise sonar system which can be mounted to an autonomous underwater vehicle or used as a stand alone platform to carry out noise surveys, track vehicles, to use sources of opportunity for target detection and image bubbles underneath breaking waves. The system is also being used to study the ambient noise in the South Florida Test Facility. New signal processing methods have been developed for this array which are best suited to the analysis of wide band signals typical of noise in the ocean. One of the objectives during the past twelve months has been to extend these concepts to active sonars for miniature AUVs.

APPROACH

(1) A series of experiments were carried out in November and December 1998 in collaboration with the AUV group at Florida Atlantic University (FAU) to evaluate Mine Counter Measure (MCM) capabilities. One of these experiments was specifically designed to test the ANS ability to track AUVs using the signature from their acoustic modem sources. The second objective of this experiment was to identify if the acoustic modem signatures could be used to insonify targets in the locality of the AUV so that they could be detected remotely by the ANS.

(2) Noise monitoring experiments were carried out in the South Florida Test Facility range during December 1998, May, July 1999, and a further experiment will be carried out in November 1999. The experiments use the ANS either in a stand alone autonomous mode or hooked up to an offshore node installed in the range during June 1999. The array hardware had to be modified to support these two alternate modes of operation.

(3) To develop the ANS technology as a small active system for imaging bubbles under breaking waves from an AUV platform. A new system was developed based on PC104 technology for the miniature AUV MADDOG developed at FAU.

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WORK COMPLETED

(1) The Modem Tracking during the MCM Experiment

The first at sea AUV tracking operation took place on November 19,1998, off Ft. Lauderdale, 1.5 nautical miles north of Port Everglades Inlet in about 20-60 feet of water. The objective of the mission was to determine the ability of the ANS array to measure and track the MFSK modulated acoustic modem signals emitted every 5 seconds by the AUV as it followed a pre-programmed course. Though there was no mine-like objects to be detected in the experimental area, the AUV pattern simulated that of a typical minefield survey. The AUV followed a lawn mower pattern with a constant 3-knot speed inside a 500-m square grid box, north of the ANS. The legs (round trip) were prescribed to be east/west, west/east, 500 m long, 50 m wide and separated by 50-m intervals. The AUV mission consisted of completing five legs then traveling back to the starting point. To avoid acoustic interference with the MFSK signal, it was decided not to use long baseline (LBL) remote acoustic navigation during this mission (this was carried out in the second experiment). The positioning of the vehicle was ensured by ultra short baseline(USBL) navigation (ORE LXT system) and periodic Differential Global Positioning System (DGPS) fixes by popping up an antenna at each 'U-turn'. This required that the AUV surface twice per leg. The data analysis confirmed that most of the measurements which were saved to disk corresponded to MFSK modem signals, which demonstrated that the triggering scheme used to detect the modem signals was operational in a light clutter environment. Selecting the measurements before saving frees memory on the hard drive and allows for more frequent 'snapshots' of the sound field, which increases the probability of catching the modem transmission. During the mission, 75 % of the emitted signals were acquired, which roughly corresponds to a measurement every 7 seconds.

To show repeatability in the ANS performance, a second experiment was carried out three weeks after the first operation. It took place on December 9,1998, off Fort Lauderdale in the Navy Range site approximately 2 nautical miles south of Port Everglades Inlet in 20-70 feet of water. The objective of the mission was similar to that of the November mission, that is to track the pings of the MFSK signal emitted from the AUV as the submarine was travelling across a 500m square grid box. Nevertheless, the experiment differed from the November mission in several points. Firstly, the 12/09/98 experiment was carried out in the framework of an actual Mine Counter Measure mission in a minefield. To achieve this, mine-like and torpedo-like objects had been placed beforehand at determined spots in the experimental area. The objects were either sitting on the bottom or moored. Secondly, to insure better positioning of the AUV, an LBL array, consisting of 5 transponders was also deployed (a transponder lay at each corner and one in the center of the operational area). The LBL interrogation was carried out every 5 seconds. The AUV followed the same lawn mower pattern as used in the previous experiment, except it only surfaced at the east turns. Thirdly, the MFSK modem signal was only emitted every 20 seconds instead of 5 seconds during the previous mission, in order to avoid interference with the LBL.

(2) Ambient Noise in the SFTF Range

In December 1998 the Adverse Weather experiment was carried out in the SFTF range. The aim of the experiment was to take turbulence, bubble distribution and noise measurements during the passage of a cold front over the warm continental shelf, off the East Coast of Florida. The ANS was used to take the

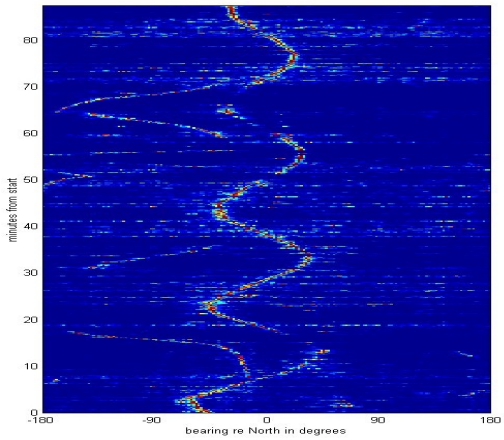
noise measurements. Unfortunately, the front which passed through the area during the span of the experiment did not produce onshore winds or any breaking waves, but some interesting noise data was collected on 5 different days with all the groups coordinated together. A good survey of the local boat traffic was made.

In May, ambient noise measurements were made in the range without other operations being conducted at the same time. Nine sets of measurements were taken in 20 minute segments, at four different sites. All but two sets of the data were acquired in the time domain. The objective was to make a survey to find any localized sources of ambient noise.

In July 1999, the ANS was used to study the diurnal variations of the shallow water ambient acoustic environment in the SFTF range. This is the first series of measurements to have taken place with connection to the MUX, which supplies power and enables data transfer to shore for up to ten separate systems. The experiment was conducted in 65ft of water. The ANS was moored on top of a concrete block at 26° 04.117'N, 80° 05.362'W. This position was 93 meters, on bearing 188°, away from the MUX. The system was deployed on Tuesday 13th July and retrieved, almost two weeks later, on Monday 26th July. This was the longest deployment time of the ANS thus far, and was possible because of the power supplied by the MUX. Unfortunately, the data transfer link to shore did not work so an Ethernet cable was connected directly from the ANS to the laptop computer onboard a boat which visited the site on a regular basis. Four sets of data acquisition were made. The dates were July 15, 19, 21 and 22 into 23, 1999. The first two missions only obtained 5 hours of data each. The third mission, starting on July 21st completed exactly 24 hours and on the last day, the ANS was left to run as long as possible, obtaining over 27 hours of data. For the last two missions, weather data was also recorded every 15 minutes from the NOVA NE weather buoy situated approximately 1250 meters East of the ANS.

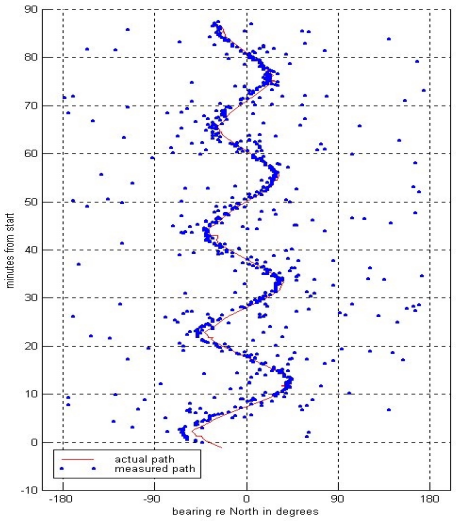
RESULTS

The tracking of the AUV during the MCM experiments was obtained by plotting the horizontal directivity of the received signals as a function of time. The horizontal directivity of each measurement is normalized over the bearing angle, so that every line in the image provides a perceptible bearing information. The calculated bearing vs. time track of the 11/19/98 mission is shown in Figure 1 and demonstrates the ANS processor capabilities for obtaining the path of the AUV from the modem signal measurements. The resulting image shown in Figure 1 reveals several arctangent traces, which correspond to boats passing to the west of the array. The presence of boats is corroborated by the spectrogram of the mission, where the broadband parts below 18 kHz (indicative of boat noise) systematically coincide to traces on the directivity image. The tracking image of the AUV was enhanced by a spectral whitening scheme based on an AR model developed by Professor M. Azimi of Colorado State University during a visit to FAU SeaTech during the Spring of 1999. This scheme has several interesting effects. First, it enhances the imaging process by emphasizing the AUV trace as well as reducing substantially the background noise. This figure also shows that the ANS tracks the AUV and boats without an interruption, which reveals the ANS multi-target tracking ability.



1. 11/19/98 mission. Tracking image of the AUV enhanced by a spectral whitening scheme based on an AR model.

An advantage in carrying out measurements with an AUV is that it records navigation data along its path. The positioning of the submersible is usually a combination of several approaches like dead reckoning, GPS, USBL, or LBL. The bearing vs. time AUV position can be easily calculated from its state data files. In Figure 2, the reconstituted AUV tracks, from the AUV positioning data and from the ANS measurements, are overlapped to match the results of tracking with the ANS sonar.



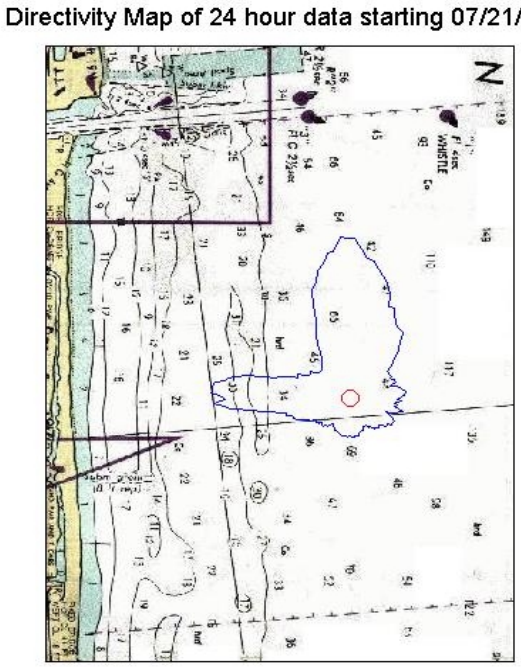
2. 11/19/98 mission. Blue: ANS measurements. Red: AUV positioning data.

The 12/09/98 MCM experiment took place in an acoustically cluttered environment. Some LBL/trackpoint pings and boat noises regularly interfered with the modem signal and were loud enough to set off the trigger independently in numerous measurements. In the processed image, only the measurements with sufficient energy above 17.7 kHz were considered in order to reject most of the

interfering signals. The results of this experiment are shown on the ANS web site [1]. The best results were obtained using the AR-based spectral whitening method to remove the effects of interference. Not only were the AUV tracks clearly discernable, but also other distinct broadband sources appeared in the records. Although they are good reflecting objects, no mine-like or torpedo-like target were located and it was concluded that the targets were not detectable in this experiment using this approach.

Ambient noise monitoring in the SFTF range has identified two major sources of sound. First, the high density of boat traffic in the area causes the most important source to be the result of boat noise. Secondly, in the absence of boats, biological noise sources (most probably snapping shrimp) are the dominat source. The directivity data, averaged over 24 hours is shown in Figure 3. The results show clearly that there are two apparent sources. The sources to the north have been identified with boat traffic travelling in and out of Port Evergaldes inlet which lies to the north. The sources to the west of the array are identified from spectra as being associated with biological noise sources, which may be populating the reef inshore of the array. Further experiments are planned for November 1999 to confirm the location of these sources.

Work on the bubble imager is currently underway and will be completed by the end of the year.



3. Directivity plot of 24 hour data from 10:53, 07/21/99 – 10:53, 07/22/99. It shows the shrimp noise to the west and the boat noise from the inlet to the north.

RELATED PROJECTS

Development of the OEX AUV vehicles at Florida Atlantic University (Dr. S. Smith).

REFERENCES

ANS web site: http://www.oe.fau.edu/~acoustics/ see MCM experiment and Adverse Weather experiment.